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Our Own and Our Cousins' Eyes

THOMAS HALL SHASTID, A. M., M. D., F. A. C. S., LL. D., ETC.

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Our Own and Our Cousins' Eyes

By
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An attempt to exhibit the evolution of the eye, so far as possible in language free from technicalities.

1926

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Our Own and Our Cousins' Eyes*

Thomas Hall Shastid, A. M., M. D., F. A. C. S., LL. D., Etc.

INTRODUCTION

THIS is a long lecture (necessarily so) and, I fear, to many of you, it will prove to be also a wearisome one. I wrote it, in the first instance, to read before the eye department of this Clinic—which department might, for very special reasons, have found it not quite so uninteresting. On being invited, however, to read the paper before a larger audience, including, possibly, a number of non-medical persons, I went through the article once more, substituting, so far as possible, popular expressions for technicalities, and condensing the paper as much as I could without completely destroying the connection of part with part. You will, however, see, as the reading continues, that even the baldest outline of this most important subject must require at least an hour, or an hour and a quarter, for its proper presentation.

My subject is, "*Our Own and Our Cousins' Eyes.*" By "cousins" I mean all the plants and all the animals which now exist, or ever have existed, on this planet: for all the plants and animals are descended from a common ancestor —a bit of microscopic protoplasm, which somehow appeared, vast ages ago, in the water of the sea.

Were I to discuss these various kinds of eyes individually, I should have before me an almost infinite task; but I propose to consider them only representatively, that is, by

* A lecture delivered at the Mayo Clinic, Rochester, Minnesota, November 24, 1925.

means of some of their typical forms. As I do this, I shall try to point out, from time to time, certain special facts which yield important information about the eyes of men.

THE EYES OF THE COMMON ANCESTOR

I have said that all life is supposed to have descended from a microscopic bit of protoplasm which appeared in the water of the sea. Now, what about the eyes of that minute, yet very important, common ancestor of us all? No one has ever seen that protoplasmic Adam. But almost every one has seen a little animal that must be very much like it —our old friend, the ameba. Let us then, first of all, discuss the eyes of the ameba.

The ameba has no eyes, or, rather, it is all eyes. In other words, it is light sensitive throughout its entire mass. You all know that most of the functions of the ameba are generalized throughout the animal's entire body, not specialized in any particular part. Any portion of the ameba may become a foot, then become a part of the body again. Any portion of the ameba can envelope or wrap itself about food; digest food, by secreting hydrochloric acid around it; and, finally, deject, or cast off, the indigestible residue. The ameba has no sex organ, because it is all sex organ. When it procreates it does so by the simple process of dividing in the middle. And so, also, the ameba's two senses, touch and sight, are likewise generalized and not specialized in any particular part. Every portion of the ameba possesses the sense of touch. Every portion of the ameba can also perceive light.

THE FIRST SPECIALIZED EYE

Passing a little higher up in the scale of life, we come to another protozöon, the Euglena viridis. This is a tiny affair, just on the border between the microscopic and the macroscopic worlds. It is of a green color, and has developed, or specialized, a mouth. Just below the mouth is

a tiny rose-colored spot. This spot, or boss, of pigment is the Euglena's eye, and it is the simplest eye, and, so far as we know, the first of all the eyes, that can be called eyes, which have appeared upon this planet. All the colored (chromatophoric) flagellates have such eyes and some of the uncolored; but the Euglena viridis' eye is perhaps the simplest of all its class.

This minute eye is both a thermometer and a photometer; that is, it measures the intensity both of the heat and of the light in the Euglena's surroundings. This is shown by an interesting experiment. A rectangular box is divided by two parallel partitions into three compartments and then ooze and water are poured over the floor of them all. Tiny passages are provided through the two partitions. Illuminate one end-compartment brightly, the middle one slightly, and the third not at all. Then place the Euglena in the black compartment. In a short time it will be found in the twilight, or middle, compartment. Place it in the brightly lighted compartment, and soon it will again be found to have passed into the middle, or twilight, compartment. Place it in the middle compartment in the first instance, and it will simply stay there. It knows what is best for it, and it gets to know that by means of the pigment eye. The pigment eye never yields its possessor a picture of the outer world; yet the Euglena, without its eye, would soon perish.

The name, Euglena, is from the Greek and means "good pupil." In truth, this pigment eye is not the ancestor of the pupil, for, as doctors all know, a pupil is not a thing, but a hole in a thing; whereas the Euglena's eye is a thing, a substance—a bit of pigment. It is, in fact—this Euglenic eye—the ancestor of the pigment epithelium layer of our retinas and, in addition, of the pigment in our skins.[1]

[1]For simplicity's sake I have employed, throughout this article, the usual names for the eyes of the Euglena and for all similar protozoan and colonial visual apparatuses—"eye spot," or "pigment eye." In truth, these "pig-

THE EYE PIT

Now the Euglena's eye is not a very good eye. One bad thing about that eye is that it is always being injured, because of its highly exposed position just below the animal's mouth, and because it projects out beyond the surface of the animal's body. So Nature seemed to say, "I can surely beat that." And so, in certain other animals, she made a depression in the surface of the body, and set the bit of precious pigment down in the bottom of the depression. This kind of eye can be seen today in some of the worms, notably the Capitellidae. The cup, or pit, appears to exist only for the purpose of giving protection to the pigment. And yet it is, very plainly, the forerunner, or ancestor, of the globe of the human eye.

ment eyes" are really composed of two parts: an internal, or pigment, layer and an outer (near the surface of the animal's body) or hyaline, layer or portion. The latter component is called by protozoölogists the "lens," or "the crystalline." This so-called "lens" is, chiefly because of its misleading name, very confusing to a person who wishes to think out the evolution of eyes. It is not a true lens, or picture-forming organ at all, but only a portion of the spot, or stigma, of light-perceiving substance. It is therefore, as one might say, merely an unpigmented part of the pigment spot. So true is this that some observers, notably Mast, believe that, in Gonium (a colonial organism) and similar animals, the so-called lens (each of the separate zoöids of the colony has its own eye-spot) is the *only* light-perceiving portion of the eye-spot. The function of the pigment layer, these observers declare, is merely to intercept the light which, passing through the (of course transparent) animal, falls upon the pigment, and so to cast a shadow on the "lens," the true light-perceiving organ.

Of course the so-called lens cannot possibly function as a lens. For one thing, it is not separated from the pigment layer by any interval or space. For another thing, it (or *they*, for often there are several "lenses" in one eye-spot) is often partly embedded in the pigment, and in some species (notably in all the colorless forms) it is entirely surrounded by the pigment.

It is hard indeed for an inexperienced comparative ophthalmologist not to think of the so-called lens as at least the ancestor of the modern lens, or image-making organ. But it is not even that. It is simply a part of the primeval light-perceiving apparatus, or "eye-spot." This fact is especially shown by the structure of the eye-spots in that much higher animal and simplest of all chordates, the Amphioxus. In these eye-spots the so-called lens generally terminates in a kind of dentation, or corner, from which extends for some distance a tiny nerve fibre. Now and then several fibres run out from one single "lens." The so-called "lens," therefore, in all these pigment eyes, is most probably the ancestor of the rods in the vertebrate retina; also (it may be) of the cones.

THE ANCESTOR OF THE TWO HUMORS

But Nature discovered, after a time, that bits of sand and other small bodies would get down into the pit and injure the precious spot of pigment hidden there. And so she filled the pit up with a viscous transparent material, one that would not flow out of the pit, and which would keep the pit filled, and so exclude all foreign bodies, while, at the same time, light was transmitted freely through this filler-material to the sensitive pigment.

Still, no real picture was formed in the eye. But it is likely that eyes like these do yield to their possessors some knowledge of the direction from which light comes. This marked a very important advance. The main thing, however, was that the viscous fluid which filled the little pit was the ancestor of man's vitreous and aqueous humors.

THE FIRST CORNEA

But Nature still seemed to think—if one may so express the situation—chiefly of safety for that bit of precious, light-sensitive pigment. So, inasmuch as foreign bodies did get down easily even into and through this viscous humor, and then did not readily get out of the pit again, Nature ran a shoot of integument across the pit, converting it into a closed pit, and, incidentally, forming the first thing that can possibly be called a cornea. This cornea, as I believe, was first opaque; for Nature has always proceeded by trial, error, and rectification. And it is a fact that some of the worms and snails have just such opaque corneas to this day, *e. g.*, the snail called Limax maximus. In a few species of snails the closing membrane can even be seen not quite crossing over. Nature, however, seeing her mistake, rectified it, making the cornea transparent.

THE FIRST LENSES

Now some of these transparent corneas, according to the law of variation, or mutation, had to be different from other

corneas. Some individual corneas, therefore, were no doubt thicker in the center than at the circumference. And behold there had come into the world, lenses. These were not true crystalline lenses, you will observe, but only corneal lenses. But we can easily imagine that the possessor of such lenses, because it received through them some kind of picture, however dim, of the outer world, had a very great advantage over many other animals in "the struggle for existence." Hence double-convex corneas multiplied throughout the world.

THE EYES OF INSECTS

Now we are ready to discuss the eyes of insects, the last of the invertebrate eyes that I will mention. Here I wish to say that I am, as a matter of course, passing by a great many eyes of much interest and even of much greater complexity than those I have mentioned. I am simply moving up what I conceive to be the central trunk of the eye-development tree and paying no attention at all to the lateral branches, however important.

Insects' eyes are of two kinds: simple and compound. We may take, as typical examples, the simple and compound eyes of the ordinary house-fly. If you look at a common house-fly, you will see, even with your naked eyes, that the fly's head consists almost entirely of two large, dark-brown lobes. These lobes are the compound eyes, and each eye is a truly wonderful affair. That is to say, each consists of more than 4000 eye-units, called *ommatidia*, placed side by side. Each eye-unit is hexagonal in circumference, like a single cell of honey. At one end of each long, cylindrical, hexagonal eye-unit, there is placed a bit of pigment—retina, rather—for each bit of pigment is now connected with the central nervous system by means of a tiny nerve fibre. And the outer end of each eye-unit has a cornea. This cornea, in its center, is thicker than at its hexagonal circumference. This makes of each cornea a

double convex lens. And each double convex lens, or cornea, throws its own tiny image of a small part of the outer world upon its corresponding retinula, or speck of retina. There is then conveyed to the fly's central nervous system, from each compound eye, a mosaic picture; a picture compounded, naturally, of more than 4000 minute picture-fragments.

These are the fly's compound eyes, two in number. What about the fly's single eyes? These are three in number, and they are situated, in the form of a triangle with its point downward, in the space above and between the two compound eyes.

Thus far we have said nothing about the focusing of eyes for various distances. Now, Nature gave to the fly two kinds of eyes, because she had felt the need for focusing, or the adjustment of eyes for different distances. She did not, however, at first, think of a very good way to accomplish this adjustment. She made for the fly two kinds of eyes: the compound eyes for distance, *i. e.*, a distance of three to four yards, and the single eyes for near: "near" meaning, in the fly's case, from one to two inches. Some insects have only compound eyes. Some have only single eyes. Most of them have both single eyes and compound. You will please to note that none of these insect eyes have any movements. The eyes are set on the fly's head as solid as so many jewels in a watch. There are, however, in some of the invertebrates, eyes that move, as, for example, the snail's eyes. That comes about from the snail's eyes being placed on the ends of two long antennae. But in no invertebrate, so far as I am aware, is there even a rudiment of an eyelid. Neither is there any iris or pupil, in the true sense of these terms.

THE EYES OF FISHES

And now we leave the invertebrates and come to the great backboned class of animals, the first of which are the

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fishes. At once we find a great improvement in eyes. But how the fish got their immensely improved eyes is extremely difficult to say. Some people believe that the eyes of fishes are directly derived from the eyes of some of the invertebrates, possibly the insects or the worms, marine worms. Others say, "No," because, in practically all invertebrates, the rods of the retina are turned in the opposite way from that in which they are turned in all the backboned beings. Others, again, say that, inasmuch as six out of a spider's eight eyes have the retinal rods turned like those of the human eye, therefore the vertebrates are all descended from the spiders, or at least from some kind of arachnid. Still others say that vertebrates did not inherit their eyes from the invertebrates at all, but that they started the development of eyes all over, made a fresh beginning. In proof of this they cite the Amphioxus, with its pigment eyes. The Amphioxus, as you all remember, has a notochord, though no true vertebral column. It is something which is trying to become a vertebrate, yet which does not quite succeed. It seems to be the immediate ancestor of the fish. At all events, some people think that eyes started all over with the Amphioxus, on an entirely new and better plan. But some comparative ophthalmologists point out that the Amphioxus's eyes are not beginning-eyes at all, but degenerate eyes, that is, eyes that have fallen from a better state because of the Amphioxus' habit of burrowing and even living in dark ooze and wet, sharp sand. So these eyes are not making a beginning of any sort, but only an ending. Then there are still other thinkers who say that eyes did indeed begin all over with the Amphioxus, but that this later scale, or ladder, of eye development started not with the Amphioxus' pigment, or degenerate, eyes, but with certain spinal visual cells which, in the primitive (transparent) Amphioxus, lie all along the spinal column, and which are sensitive to light. As the Amphioxus became less transparent in some of its species, and grew more like a

fish, its spinal visual cells moved to the surface of the body and became, two of them at least, true vertebrate eyes. Still other persons declare that the eyes of the vertebrates are not descended either from pigment eyes or from spinal eyes, but from tactile corpuscles in the skin of some of the most primitive backboned animals. Whatever the truth among these theories may be, we see one thing clearly and that is that the subject of eye-development becomes, as we pass from the invertebrates to the fishes, one of very great obscurity indeed. This obscurity, however, I may remark in passing, is no greater than that which surrounds the pedigree of man in general. As one scientist has truly phrased the situation, "We do not yet know, after more than a century of morphologic study, even whether man and the other vertebrates have descended from a segmented, or an unsegmented, ancestor."

At all events, we now come to consider the eyes of fishes. Of a sudden all is changed. People are accustomed to say, ridiculously: "The poor fish." But the fishes have presented to the world many fine matters of inheritance. For one thing, the backbone itself. As if this wondrous gift were not alone sufficient, the fishes have introduced also a true crystalline lens; not a merely corneal lens, but a lens posterior to the cornea and separated from it by transparent fluid. They also introduced true focusing arrangements. In addition they have given us the iris and the pupil, also extrinsic eye muscles, and they almost, but not quite, introduced eyelids.

RETINAL REST

And now, speaking of eyelids, I shall have to digress for a moment to the eyes of men, in order to bring out clearly the importance of eyelids. This importance is due to the need for retinal rest. Retinal rest, in man, is secured chiefly in two ways: (1) by motion blindness and (2) by involuntary winking. Let us first consider motion blindness.

Whenever our eyes are in motion, they are stone blind, excepting only when they move without changing the point of fixation. Astounding as is this fact, it is scarcely ever borne in mind, even by ophthalmologists. Yet any one can easily convince himself of the truth of the statement. Let him stand before a mirror, and look at the image of one of his eyes. Let him look first at the right side of that eye, then at the left side of the same eye, and then back again. Never, so long as he lives, will he see his eye in motion. The reason is that, just so soon as an eye begins to move, it is blind. We are never conscious of the blind interval, chiefly because the picture which is last seen before the eye begins moving, persists in the sight center of the brain and thus laps over the interval during which the retina is blind. But the chief fact is that the retina, by means of its motion blindness, gets minute intervals of rest with very great frequency all through our waking hours. In this way, too, the blurry and useless pictures which we should receive if the eyes saw while in motion are avoided.

But there is yet another way in which retinal rest is secured: namely, by the involuntary winking of the lids. From three to six times a minute this involuntary winking takes place, and it very much adds to the quantity of rest which the retina receives.

There are other uses of eyelids: protection against injuries by foreign bodies and from other traumata; the frequent spreading of the tear (which is secreted at the upper and outer angle of the eye) in a thin layer across the front of the eye, to keep the eye moist and bright; then, too, the moving of the tear on to the mouth of the tear sewer, which begins at the inner angle of the eye and runs down into the nose.

In some diseases retinal rest is greatly interfered with; for example, in exophthalmic goitre. In this affection winking becomes less frequent, or disappears entirely.

Then, too, the eyeballs, being strongly protruded and rather tightly fixed, are more or less motionless, and so the retinal rest from "motion blindness" is also practically abolished. Hence, in this disease, the poor retinas are practically worn out from lack of rest. Bandaging the eyes, in these cases, does more than prevent ulceration of the cornea: it also provides sufficient rest for the exhausted retinas. In paralysis agitans, facial paralysis, and ophthalmoplegia externa, we have a similar situation, and one which, as an element in the case, is almost universally ignored. And, in fact, in many otherwise unexplainable cases of asthenopia, we find, if we carefully investigate, that the cause is some kind of interference with retinal rest. Some hysteropes wink only once a minute, instead of three to six times, and so on. I have made numerous investigations into this subject (not yet published) and I confidently recommend the topic of "retinal rest" to the oncoming generation of ophthalmologists as one of the most promising for original investigation of any which I know.

THE BEGINNINGS OF EYELIDS

Now to return to fish and eyelids. There were no eyelids in the world before fish. And fish simply made a beginning of eyelids. No fish, to this day, has a functioning upper or lower eyelid. But, in a very few species, there do exist fixed dermal folds above and below. And in some sharks there is a membrana nictitans, or eyelid in the inner corner of the eye. This lid is really a functioning lid. By the contraction of its muscles it runs outward across the front of the eyeball, and back to the inner corner of the eye. This membrana nictitans, as we shall see hereafter, is the chief functioning eyelid of snakes and birds, and a vestige of it still remains in the human eye in that which is called the "plica semilunaris."

FISHES' EYES AND DEPTH OF WATER

Before considering fishes' eyes further, let us classify these eyes according to the depth of the water their possessors inhabit. Fish that live in the uppermost layers of the sea have pretty good eyes, because they live in fairly well illumined water. Those that live in deeper and deeper water have increasingly larger and larger eyes, with larger and larger pupils, in order to catch what little light is stirring about them. These eyes are also nearer the top of the head, because the light which they do get comes from above. At length, in the very deepest depths, where no light ever is found, except, perchance, some mysterious bit of phosphorescence, the eyes become smaller and smaller. Finally, in the blackest abysses of the sea, eyes generally become mere rudiments or disappear altogether. Fish, too, that live in dark caves are totally blind, some even eyeless.

BLIND CAVE DWELLERS AND RED LIGHT

And here I am going to digress again, because of an extremely important and new subject. Blind cave-dwelling animals of various sorts have recently been made to see. Let us consider the work of Professor Przibram, of Vienna. This man, in an artificial cave, bred successive generations of the blind, cave-dwelling amphibian, Proteus. By exposure to red light he developed, in the very first generation, the pin-head, perfectly blind eyes of Proteus, into large and fairly well functioning organs. No other kind of light than red would do the work. Also, exposure, even to the red light, of the adult Proteus gave no results. I have watched carefully for some application of these astounding facts to the treatment of the human eye; but, thus far, have found absolutely nothing done, which is a fact still more astounding. Why should not some of the younger ophthalmologists investigate, in the human subject, the effects of red

light on microphthalmos, microphakia, congenital amblyopia, and various other deficiencies in ocular development?

THE EYES OF TYPICAL FISH

But to return to the fishes. Let us take as typical the eyes of fish that live in well-lighted water. These eyes are all short-sighted, because, even in the best lighted water, no eyes can see very far. A fish's cornea is always flat, because any convexity which it might possess would be completely nullified by the water fitting round it, since water has substantially the same index of refraction as the cornea. Moreover, flatness of cornea is an advantage, because a flat cornea is not so easily injured as a prominent one, and nearly all fish, we recall, have no protection from eyelids. If this were the whole story, a fish would be from 32 to 40 diopters far-sighted. But, to offset the flatness of the cornea, there is a spherical lens, with a high index of refraction, which more than overcomes the far sight of the cornea, and actually makes the fish a few diopters short-sighted, which is precisely the condition he needs in his habitat.

Fish are about all color blind. Tell this to a fisherman with his brightly colored flies, and he will laugh at you; nevertheless, it is a demonstrable fact.[2] Fish have also a very restricted visual field. Anything below the level of the head they scarcely see at all.

[2]Zolotnotsky, in 1901, made the following false experiment. For a long time he fed certain fish, which were kept in an aquarium, with maggots of a dark red color. He then fastened inside the aquarium wall woolen imitations of these maggots, but of white, green, yellow and red. The fish paid no attention at all to the white and green, hesitated a little before the yellow, but darted immediately at the red and ate them greedily. From this experiment Zolotnotsky concluded that fishes have color sense. The experiment was about on a par, in the matter of scientific accuracy, with the careless observations which some people make when fishing.

A few years after Zolotnotsky's experiment, a long series of very careful experiments on the color sense of fishes was made by Hess. It was well known to Hess that a completely color blind human being easily learns to tell colors apart and even to name them as normal persons do, simply by noting the

I have said that fish introduced accommodation into eyes, *i. e.* a focusing apparatus. Their accommodation is produced in several ways, but chiefly by a band of contractile tissue running from the head of the optic nerve to the posterior surface of the lens. This band is called the "falciform process." When it contracts, it pulls the lens back nearer the retina. When it lets go, it permits the lens, by virtue of its elastic attachments, to run forward again. One may see, from these facts, that the fish's eye is at rest

difference in the illumination, or relative quantities of light given off by objects of various colors under the same brightness of light. (Black and white are not, in this connection, regarded as colors; neither are grays, which are simply mixtures of black and white.) That is to say, to a totally color blind person, white looks white and black looks black; also gray (any mixture of black and white) looks gray. And all the various colors look gray to him also. Green, for example, looks a very light gray; yellow, a gray of medium darkness; and red, a very dark gray, almost a black. For this reason it is that, when examining railroad men, lighthouse keepers, and so forth, for color blindness, we must be exceedingly careful or we shall make serious mistakes. Hess, keeping in mind these things, conducted his experiments with very great accuracy. And they all lead without one single exception to the same conclusion—namely, that fish have no color sense.

Here are some of the simpler experiments. A red bait and a dark gray bait (which, to a totally color blind person, look exactly alike) were fastened at intervals about the aquarium walls, and all were equally illuminated, as well as provided with exactly the same backgrounds. The fishes swam to and ate both kinds of bait, red and dark gray, indifferently. Again, a series of gray baits only, ranging from very bright grays to very dull grays, were fastened to the aquarium walls, and the fish once more permitted to enter the aquarium. They all swam to the dark gray baits, and ate them immediately, leaving unnoticed the lighter grays. It was, therefore, the intensity of the illumination reflected from the baits (not shed upon them) and not color sense at all, which had guided the fishes.

Here is one more of the experiments. There was fastened against the outside of one aquarium wall, a dark blue paper. Inside the wall, and against this background of dark blue, were hung a number of dark red artificial baits, of such a shade that the quantity of light reflected from a given unit, say a square inch, of bait and of background was exactly the same. The fish, being permitted to enter the aquarium, were not able to find the baits, although the contrast, to a normal human eye, between the dark blue and the dark red was exceedingly striking. When the background was made a much lighter blue, or a much darker blue, then the fish would shoot to the bait without the slightest hesitation and devour it greedily.

Similar experiments have been conducted in ponds, streams, and lakes, all with the same results. But the experiments in aquariums and reservoirs have been the most conclusive, because, in the artificial containers, the fish were under complete control, *i. e.*, they could be kept hungry at will, etc.

when focused for near, but that it is engaged in active accommodation when looking at a distance. This is just the reverse of the situation in our own eyes. In other words, fishes have "negative accommodation."

The falciform process should have a great interest for ophthalmologists. In amphibians, reptiles and birds, it has lost its attachment to the posterior surface of the lens, but retained its attachment to the optic disc; and, in these classes of animals, it is called "the pecten." In many snakes it has disappeared altogether. It does not occur in human beings, except in the form of what is called "the persistent hyaloid artery." This artery, in the last few weeks of fetal life, should shrink and disappear. But sometimes it persists, and then it is seen by the ophthalmologist as a thin, gray vascular cord, running from nerve-head to posterior surface of lens, exactly in the path of the old accommodation band, or "falciform process" of the fish. Sometimes it presents a number of loose, grayish tags, or flaps. The vision in these cases may be normal, but often it is low. One can hardly understand the persistent hyaloid artery without some knowledge of the fish's eye; and one is also obliged to speculate, in view of the remarkable results of Przibram with the undeveloped eye of cave animals, as to what the effect of continued exposure of the eye to spectrum red light on a persistent hyaloid artery would be. If you ever have a favorable opportunity, make the experiment and see. I would suggest that a baby with eyes suffering from any sort or kind of arrested development, should be kept for some time in a black room, protected from sunlight, but with free ventilation and a continuous ruby red light. From time to time the eyes could be bandaged, and the body of the child exposed to ultra-violet radiations, so that the child could not suffer from sunlight starvation. In view of the fact that light is the raw material which eyes are constantly manufacturing into

vision, it is extremely strange, especially in view of the Przibram experiments, that the therapeutic effect of light generally on human eyes has never been worked out.

THE FIRST IRIDES AND PUPILS

Fishes also introduced into the world the iris and the pupil. The pupils of all fishes are declared by some observers to be oval. I have never found one single fish's pupil that was. They are all round, except a few very unusual ones. Of course you must not look at the pupil of a dead fish, which is round as a matter of course. Even a cat's pupil, which is long and vertical, when contracted, for looking up and down trees, is perfectly round in low illumination and when its owner is excited or dead.

But all the fishes' eyes that I have examined have had round pupils, and these, by the way, have had only a little response to light.

Before the fish, there were no extrinsic muscles of the eyes. In some of the molluscs and arthropods, eyes were set on eye-stalks, and these stalks were movable. But there were no eye muscles proper. Now, in many fish, there are muscles that move the eyes in their sockets, though only to a slight extent.

There are fishes with thermometer eyes and fishes with incandescent eyes which illuminate the sea so that the other kinds of eyes of the same animal may have vision. The choroid coat of some fishes' eyes is a wonderful reflector, just like the choroid coat of cat, dog, deer, and so forth, or animals whose eyes are generally known to shine in the dark. The part of the choroid that does the reflecting is called the "tapetum lucidum." This tapetum runs away round in the front part of the eye, and there forms the anterior layer of the fish's iris or the *argentea*. So the fish's eye shines in the dark, both because of the light reflected from the interior of the eye and also because of the light reflected from

the anterior surface of the iris. In the cat, dog, lion, and so on, the reflection is only from the interior of the eye.

I wish I had time to describe the eyes of many peculiar fish: those of the Anableps tetrophthalmus, for example, which have, each, two pupils, one for seeing in water, the other for seeing in air. Also the eyes of the pleuronectidae; the flounders, and so on. These eyes, in the fish's youth, lie, in the usual way, one on each side of the head. But, as the animal grows older, it gets to swimming only along the bottom of its habitat, scraping constantly the gravel and sand with one side of its head, and so its skull twists until the two eyes lie on one and the same side of the head, or the upper. This fact you can easily prove to yourself in almost any fish market. All the pleuronectidae, or side swimmers, have such eyes. In one species, the eye that shifts does not pass round the skull, but actually goes straight through it, till it comes to lie in identically the same socket as the other or non-migrating eye.

THE EYES OF AMPHIBIANS

The next great class is the amphibians. These developed from those fishes that had lungs, the dipnoi. The fishes with lungs could breathe either in air or in water, and so they often flopped out on the land, and, in time, at least some of them learned to live there. So life passed from water to land. The pectoral fins became shoulders and arms, the ventral fins became hips and legs. The scales that covered the body were lost, the skin becoming naked. The resultant beings are called amphibians, and they are higher in the scale of life than are the fishes. To them we owe a number of important inheritances. One of the very greatest is, of course, the transition from aquatic to terrestrial life. This transition is still not complete, even in ourselves, for every embryo child, at a certain stage of its development, has gills, just as surely as the tadpole, the water

stage of the frog, has gills. Another gift of the amphibians is the thumb, without which there never could have been a human hand. Look at the hand of the frog today, with its little, human-like "opponens." To Mr. Frog, or Mr. Frog-like, the world owes also its vocal cords and speech. Strange to say, the first vocal utterances on earth were probably the English word, often repeated: "Work, work, work! Work, work, work!" Listen and you can hear the frogs still calling the old password to success. After the fashion of most advisers, however, frogs do no work themselves.

The amphibians developed the eyelids further than the fishes had done, especially the lower eyelid. Watch a frog today, and you can see him wink upwards. Whereas we human beings wink with the upper lid downwards, the frog winks with his lower lid upwards.

Few fishes have any tear apparatus: wet eyes need no tears. When they do have a tear apparatus, it secretes not tears but fat; something like the Meibomian secretion in human skin. The amphibians, however, presented the world with true lachrymal secretion and drainage.

AN EYE IN THE BACK OF THE HEAD

Some of the amphibians had a median, or pineal, eye; an eye in the back of the head. Many of the gigantic saurians, too, of Mesozoic time had this eye, and, in any geological museum, you can still see, in the back of the giant lizard's skull, the hole through which this strange eye formerly looked out. In ourselves the hole has boned over, and the eye has shrunk up into the so-called pineal gland. In the present day hatteria, of New Zealand, this eye is present early in life, and is almost a functioning eye, for lens, retina, pigment, cornea, are all present. But the eye degenerates as the animal matures. The pineal eye made its first appearance in the world far back among the invertebrates. It was, indeed, an invertebrate eye (that is,

one with the rods turned toward the vitreous, instead of away from it, consequently with no blind spot) but it persisted (still in the invertebrate form of eye) through some of the fishes, through the amphibians generally, through the lizards, and then began degenerating; possibly because the vertebrates had other eyes, and these were of the vertebrate (for some unguessable reason a more suitable) type. One cannot help wondering what the effect of spectral red light would be on this retrograde metamorphosis.

Many of the amphibians have fair color vision, but, as in the case of the fish, none have a retinal sharp spot, or macula lutea; and, partly for this reason, their sight is in general poor.

THE EYES OF REPTILES

The reptilia added little to eyes. A curious fact is that many persons, even scientists, believe that snakes have no eyelids. The truth is that the snake has, in addition to the membrana nictitans, both an upper and a lower eyelid. But these lids are fused together and are perfectly transparent, so that they form in effect an immobile transparency over the front of the eye. This transparency is often called by naturalists "the scale," or "the crystaline scale." It is simply a transparent duplex eyelid. Being extremely hard, it protects the snake's eyes from scratches as he glides along among thorns, briars, sharp sand, and so on.

At the skin shedding (annual, twice-annual, or thrice-annual, according to circumstances and the species) the scale is shed with the rest of the skin. Just before the shedding, the scale becomes opaque, and the animal is, as country people all know, blind at that time.

Snakes have no macula lutea, and, in general, they have very poor sight. Most of them see hardly anything, except objects in motion. Most snakes are nearly deaf too, so that their knowledge of the outer world reaches them mostly

by way of the little forked tongue, which is probably the most wonderful tactile organ in existence. This little affair is almost constantly out—feeling, feeling myriads of vibrations in the atmosphere, which, to our coarse sense of touch, are simply as if non-existent.

THE EYES OF MAMMALS

From the hideous reptiles branched off both the mammals and the birds: which was the earlier, we do not know.

As a matter of convenience, let us first consider the mammals or those animals which suckle their young. These we may classify as non-primates and as primates, the primates including monkeys, apes and men. There are no distinct maculae luteae in any of the non-primates. Many of these have no maculae at all. None have any foveae. Scarcely any of them have any overlapping of the visual fields of the two eyes, and those which do have some overlapping have no true stereoscopic vision. Hares and rabbits actually have the fields overlapping behind their heads, but they have no stereoscopic vision behind. In nearly all the non-primates, the eyes are not set out on the front of the face, but at the side of the head; and the human foetus in its earlier stages has its eyes also laterally placed, thus helping to recapitulate the story of its undoubtedly animal ancestry. Most of the visual fields in the non-primates are very narrow, and the range of movement of eye in socket is slight, sometimes negligible.

The ciliary muscles of most non-primates are small, as in the cat and dog, or altogether wanting, as in the rabbit.

THE PUPILS OF MAMMALIAN EYES

A very great difference exists among mammals in the shape of the pupil in the contracted form. Practically all pupils when dilated, whether from emotions, or from the dark, or from drugs or death, are round. The pupils of

nearly all the ungulata, or hoofed animals, are, however, broad horizontally, even when dilated. A goat's pupil is very long horizontally, even when dilated to the utmost. Atropine and excitement combined could not increase the vertical diameter of a goat's eyes, which I examined, to more than one-third the horizontal diameter. In the contracted condition, though, the pupils of not a few animals vary greatly from the round form. Thus, the pupil of the domestic cat, when contracted, is vertical, very narrow, and with quite sharp angles above and below. In fact the cat's pupil can get so narrow horizontally that it actually ceases to exist at all. Moreover, a cat, whose eyes I used to examine a good deal, had the very obvious power of contracting and dilating her pupils at will, just like a bird. Whenever I stroked this cat, she would purr rhythmically, now and then omitting one single purr, and, in place of the purr, substituting a complete obliteration of her pupils, and following that by a moderate dilatation of them. She would then resume the purring, keeping, all the while, very good musical time. The cat, of course, needs a vertical pupil for the purpose of hunting its prey up and down trees: it must have a long vertical field. Comparative ophthalmologists used to say that the vertical pupil of the cat was, in effect, a stenopaic slit for the purpose of overcoming the high astigmatism assumed to be present in all cats' eyes. Careful refractions of numerous cats, however, by myself and others have shown that cats' eyes are not nearly so often affected with astigmatism as are men's. There is a popular impression that all the felidae (cat family) have vertical pupils. But this is a mistake. The lion and all the larger felidae have round pupils, even in contraction. The horse's pupils are very peculiar. They are wide horizontally, so that the animal, when grazing, can see sidewise, both to right and to left, over a wide expanse of ground. Near the center of the upper border of the pupil, and again near the center

of the lower border of the pupil, are seen, attached to the iris, a number of small black bodies. These are called "corpora nigra." In strong light these bodies, moving from above and from below, serrate into one another, like saw teeth, thus obliterating the central part of the pupil entirely, and leaving two round pupils, one at each end of the horizontal diameter of the eye. The horse's eyes are placed prominently up and out on the corners of its head, so that it can, in fact, aim a kick at a wolf—the horse's natural enemy —without the head turning. I should like to say more about mammals' pupils, but must pass on. Suffice it to say that the corpora nigra are simply an eversion of the pigment layer of the iris, so that when, in the human subject, you find such an eversion by way of anomalous development, you may, if you choose, regard the condition as a reversion to an ancestral, or animal, type.

THE MEMBRANA NICTITANS IN MAMMALS

Many of the non-primates have a large, active membrana nictitans. The horse, for example, is continually cleansing the dust from the front of his eye and spreading over that front the highly antiseptic secretion of the gland which lies on the posterior surface of the membrane, or Harder's gland. In fact such animals have, in effect, at the corner of each eye, a fairly good and ever present oculist.

In the human subject, we may say again, in passing, the membrana nictitans is merely vestigial, and is called the "plica semilunaris." It is often diseased, as I have found, and often becomes the nidus for re-infection of the conjunctiva in recurrent conjunctivitides. And chronic inflammation of this vestigial organ should be carefully attended to—as it generally is not. There is often a sma'l space, or pocket, behind it, and this potential cavity, small as it is, should, in all these cases, be thoroughly disinfected and cured.

THE FUNDUS IN MAMMALS

The fundus of the non-primate eye is simply a marvel for its vast variety of ophthalmoscopic appearances. A day in the zoo with your ophthalmoscope will prove an event in your lives. In the felidae, for example, the optic disc is always deeply cupped so that the blood vessels dip and are not continuous in appearance as they run from the retina over the rim of the cup and down into the depression. This condition explains what is called in human beings a "physiological excavation", *i. e.*, a deep cupping which is not due to glaucoma. The physiological cupping is simply a reversion to an ancestral type of disc. It cannot be otherwise explained.

In all the felidae and some of the other non-primates, there is a tapetum lucidum. This tapetum is what makes the eyes of such animals "shine in the dark." You will remember that we found the tapetum lucidum first in the fish; only, in the fish, the tapetum covers the entire eye-ground and, passing round to the front of the eye, forms the anterior layer of the iris, where it is known as the "argentea," or silver membrane. (It is the middle coat of the choroid, or else a coat between choroid and sclera, and, in fish, it has a brilliant metallic lustre.) In other words, the fish's eye reflects light from the anterior surface of the iris, as well as from the entire interior of its eye. Now, in the felidae, or cat family, and indeed in all the other mammals whose eyes shine in the dark, there is no reflection from the anterior surface of the iris, but only from the interior of the eye, and, further, only from the central part of that interior. Take, for instance, a dog's eye. The central part, as you view it with your ophthalmoscope, shines with a yellowish lustre more bright and beautiful than that of beaten gold. That is the central part of the fundus and of the tapetum lucidum. Round this is a green area, also unspeakably brilliant and beautiful. Then comes, most peripheral of all, a dark zone

known as the tapetum nigrum, or black carpet. This reflects no light, and, furthermore, it is partly or wholly blind.

All eyes that shine in the dark do so by virtue of their tapetum lucidum, or concave reflector in the fundus behind the retina. The purpose is to enable the animal to see better in the dark. The little light that is stirring in the outer world enters the pupil, passes through the transparent retina, and on to the middle layer of the choroid, the tapetum lucidum. The retina utilizes this light for vision as it passes through that membrane. It utilizes it again, as the same light is reflected from the tapetum out through the retina, then through the pupil, and on into the outer world, where it falls on the same object from which it came. Here it is joined to the fresh, original light, coming from the object, enters the eye once more, and so on. Each and every ray is in fact utilized until it has been completely absorbed, or stopped, by its frequently repeated transmission through the various media. And thus the carnivora and some other animals, whose vision is very much poorer than ours by day, have vision much better than ours by night. And that is why, as Treacher Collins has admirably pointed out, primitive man lived in great terror of the dark. He was eater by day, but eaten by night. And this is why all human children, even to this present time, dread the dark instinctively and often terribly. It is also the reason why, for long ages, the human race lived, by night, in caves or in lake dwellings.

PECULIARITIES OF HORSES' EYES

Most people suppose that only the carnivora have eyes that shine in the dark. But many other animals have such eyes. The eyes of the horse, for example, are not infrequently seen to emit in the dark a bluish scintillation. This always comes from the upper part of the horse's fundus. Use your ophthalmoscope on a horse, and you will see that,

at the upper part of the fundus, there is a tapetum lucidum. The lower part is, strangely, covered with a dark tapetum nigrum, and it is practically blind. The consequence is that the horse sees almost nothing above the level of its eyes, as I have often demonstrated; while, on the other hand, a horse can see the road, even of a dark night, vastly better than can any human being. In my early days, I, as a country doctor, was often caught far out in the country, of a dark night, without any buggy lantern. All I had to do, then, was to tie the lines to the front rib of the buggy top, and let the horse find his own way home. This he would always do with perfect safety to us both, though the night was sometimes so black that I not only could not see the road, but could not even see the horse or my own hand.

For countless ages, the horse's eyes, set out prominently on the corners of his head, have been exposed to the effulgence of the sky and the sun, and, consequently, the lower part of his retina has been completely burned out. He, on the other hand, has always been a runner and grazer, and therefore has needed to see the ground well, and, in consequence, he has developed, in the upper part of his eye-ground much the same kind of structure as the carnivora possess in the central part of their eye grounds.

There is a tapetum lucidum in every human eye, but it does not reflect much light. That structure, in our eyes, is simply the middle, or connective tissue, layer of the choroid. It possesses little metallic lustre. It is, however, that which we see chiefly when we look into the human eye with an ophthalmoscope, because the retina is transparent except for red rays. There is also, in each human eye, a tapetum nigrum. This, however, in our own eyes, is called by a different term—the *pars ciliaris retinae*. I wish I had time to talk to you about the eyes of rabbits and goats especially, but I must hurry on.

THE EYES OF PRIMATES

A few words, now, about the primates—monkeys, apes and men. The eyes of the galago (one of the lowest monkeys, or pro-simiae) are very instructive indeed. These eyes have retinitis pigmentosa normally. All the symptoms are present: nyctalopia, poor vascularization of optic nerve and retina, the grains of snuff-like pigment, scattered thickest in the peripheral part of the eye-ground. The galago almost certainly occupies a conspicuous place in man's pedigree, so that it is more than likely that retinitis pigmentosa, in the human being, is simply a degeneration, or reversion to an old type of eye. I have heard ophthalmologists say that retinitis pigmentosa is almost always the result of inherited syphilis. I cannot agree, further than that I admit that, in inherited syphilis, there is a strong tendency toward reversions of various sorts. There is the same tendency in the children of consanguineous marriages, and in twins and triplets from marriages of any sort or kind.

Zoölogists have found that the galago is a dark-loving animal, and that, if it be forced to dwell in strong light, its sight rapidly diminishes until, in a few years, the vision is entirely gone, whereas, if the animal be allowed to continue living in the low illumination which is normal for it, it will keep the sight with which it was born. Moved by this fact, and believing retinitis pigmentosa to be a reversion to this old type of eye, I have long caused my patients suffering from retinitis pigmentosa to avoid all strong light with the utmost care. I have also had each and all of them wear some of our modern absorptive lenses, and it has seemed to me that the progress of the disease has often been held in check by so doing. In some cases there was even a very decided improvement. I implore all ophthalmologists to keep their retinitis pigmentosa patients, in one way or another, out of strong light.

The pupils of all the primates are round. These eyes,

too, are placed less laterally and more frontally than in the non-primates. There are also maculae in all these eyes, and strong muscles of accommodation. In all the monkeys, the eyes can be converged and stereoscopic vision obtained but not long maintained. In the apes, stereoscopic vision is more easily reached, and maintained with less effort. But only in man, of all the mammals, does there seem to be continuous, easily kept, binocular and stereoscopic vision. Even in the human child, however, the eyes do not, as a rule, move in perfect unison with each other till about three months after birth. That is because stereoscopic vision, in the history of life on this planet, is an extremely recent development. The same fact explains the ready loss of binocularity in many persons from errors of refraction and so forth. You will remember that, even in some of the fishes, there was some slight pupillary response to light. That is why the human infant has a good light reflex even at birth. This light reflex inheritance has come a long way, and is pretty well established.

I should add that the eye grounds of all monkeys and apes are almost exactly the same as those of the black race of mankind. There is the same dark chocolate hue of the choroid, the same shot-silk appearance of the retina, and so on.

DOMINANCY AND SERVIENCY IN EYES

There is one peculiar thing about man's eyes that we do not find at all in the eyes of animals, namely, dominancy and serviency. Now in all mammals the eyes are *two* little cameras, not just one. In each of these cameras there is produced a tiny picture of the outer world. But, in the brain of a man, only one, single, composite or stereoscopic, picture is seen. And the peculiar thing as to the vision of a man is that to the formation of this single stereoscopic picture the two pictures, one in each eye, do not contribute equally. In a right-handed person, the right eye contributes

most of the picture: in myself about ninety-five per cent. In my wife, about one hundred per cent, under all ordinary circumstances. In a left-handed person, the left eye contributes the most of the picture; generally, but not always, for, even in left-handed persons, the right eye is often dominant. In other words, the right eye is nearly always the window that the brain really looks out through, even when both eyes are directed at exactly the same object, and when the sharpness of sight of both eyes is exactly the same. The right eye gives to the brain the details of the outer world, the left eye just coming in now and then with a little accessory information as to certain matters. In some persons the left eye has no vision, when both eyes are in use, except central vision, or upper- or lower- or right- or left-half-vision. When the right eye is closed, in all these cases, then the left eye promptly extends its visual fields to the normal limits of the right eye. I have long experimented with these matters, and hope some day to make a complete report. This is all I have to say on this subject just now.

Dominancy and serviency in eyes, like right-handedness and left-handedness, have come into the world very late; that is, as a consequence of the evolution of a speech center. A right-handed and right-eyed person always has his speech center on the left side; and, generally, possibly always, the converse is true. In no animal, so far as I have been able to learn, is there any such thing as handedness or dominancy. This, you will observe, is a peculiar state of affairs. Man did not much more than develop binocularity and stereoscopic vision than he proceeded, through the development of a speech center, to lose the stereoscopic vision very largely, though not the binocularity. This keeping of binocularity, at the same time with the steady loss of stereoscopicity, is producing in the human subject a condition which, however much it is being ignored, will eventually and necessarily result in consequences of vast importance.

THE EYES OF BIRDS

Of the eyes of birds I have time to say little. These eyes, nevertheless, are the finest and most remarkable of all the eyes of earth. Birds' eyes are often both telescopic and microscopic. Their focusing organ is chiefly the cornea, not the lens. Their visual acuity is almost incredible, being, in some instances, one hundred times as great as that of human eyes. A bit of grain, or a tiny insect, which human eyes can barely see at a distance of one yard, these birds can see readily and distinctly at a distance of a hundred yards. We have all seen small birds, in the twilight, make a dash for an insect, apparently on a leaf or twig more than a block away, and pick it off accurately while still flying. Swallows do this constantly by very dull evening light.

This remarkable visual acuity in birds is almost a necessity, because the sense of smell in birds is exceedingly poor, since the olfactory passages are encased in horn. Even vultures (contrary to popular supposition) do not smell their food, even though it be carrion, but see it.

Birds do not see blues and violets at all. This helps in their distance vision, because the haze which hangs about distant objects, and which, for our eyes, renders them invisible, for birds simply does not exist. Birds, on the other hand, see infra-red radiations, which, for us, affect only the temperature sense of the skin and not the retinas at all.

INFULAE AND ACCESSORY MACULAE IN HUMAN EYES

Some birds have no macula, some have a nasal macula, some a temporal and some both a nasal and a temporal. There is often an "infula," or band, of central vision, instead of a mere spot or macula. Human strabismus is sometimes due to the existence of either a secondary macula or of an infula, or band, instead of a mere spot, of central vision. We are occasionally astonished to find that a human

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eye which, with its full correction, can only read, say 20/50 at a distance, displays perfectly normal visual acuity at the test for near. We are accustomed to explain these cases by saying that the better vision for near is due to the pupillary contraction which occurs consensually with convergence, and, to some extent, with accommodation. This pupillary contraction, we say, has limited the vision to the most central part of the cornea, thus excluding from activity in the matter a zone of cornea which is optically very erroneous, but which, at the far point, the patient was obliged to use. This is indeed the true explanation in some cases. In other cases, the retinoscope shows no such difference between the absolutely central and the paracentral refraction. The truth is that the eye in question has, like some birds' eyes, a double macula, one for far and one for near. In a few cases there seems to be, as in other birds, an infula, or band, of sharp vision, and no macula or maculae at all.

OTHER PECULIARITIES OF BIRDS' EYES

Nearly all birds have the eyes on the sides of the head. Such birds, of course, can have no binocular vision. Yet many possess stereoscopic vision without binocular vision. This they get by virtue of the fact that they have two maculae in each eye. This gives in the one eye the two pictures from two different angles which constitutes the *sine qua non* for stereoscopic vision. Probably the infula, or band, of central vision, accomplishes, in some birds, exactly the same thing, only in a better way.

There are no bloodvessels in any bird's retina that I have ever seen or heard of. This absence of vessels helps to sharpen the bird's sight, because bloodvessels ramifying in the very substance of the retina, as they do in our own eyes, must interfere very much with visual acuity.

Birds have voluntary control over the size of their pupils, as Casey Wood has pointed out and as anyone can see. The bird's pupils are round, whether contracted or dilated, ex-

cept in a very few species, *e. g.*, the owl, which is a tree-hunter like the cat.

WHAT IS GOING ON IN HUMAN EYES NOW

We have now finished with the evolution of eyes on this planet, even up to the present day. I have, however, omitted the eyes of plants—this for lack of time. I realize as well as any one that this is a very sketchy and fragmentary presentation of the subject. However, in all the recent hubbub about evolution, almost nothing has been said as to the evolution of eyes. So, inasmuch as eyes present, in my opinion (though contrary to the opinion of many observers) the clearest case for evolution of all the various organs of the body, I have prepared this paper, and I hope that I have been able to show the subject clearly, however imperfectly in other respects. And now, before I close, I wish to say a few words on the present progress (or degeneration, as some would say), also the probable future development of human eyes.

The greatest evolution of the human eye which has, of late, taken place, has been in the way of developing marvelous artificial accessories to that organ. Evolution of the fleshly eye, in other words, has been, for man, in the more recent stages of his progress, much too slow. His fleshly eye might, in the course of long ages, have become both microscopic and telescopic, like a bird's. But man, being an impatient animal, could not wait. So he invented the microscope and the telescope. He also invented the spectroscope, even the X-ray apparatus (which permits him to see through opaque objects), also numerous other optical instruments. And the beginning is hardly as yet!

But what about the human eye itself, as distinguished from artificial accessories? Is not the organ itself to develop still further? If so, in what ways? The answer is "anybody's guess," so here is mine. It is a well known fact that

the human eye is at rest when gazing at a distance, but very hard at work (especially at work focusing) when looking in the near. This is the exact opposite of the situation in the case of many birds and of all fishes. And, until two or three generations ago, it was, no doubt, a very great advantage for man to have eyes which are at rest when looking in the distance, for man, during nearly all his time, was engaged in looking far away, hunting for something to kill and eat. In the last three generations, however, book education has become almost universal, and now man is not so much a distance-looking, as a near-looking, animal. He reads, writes, repairs watches, cuts gems, examines pictures, and so forth. Nature has sought valiantly to help his eyes adjust themselves to the new set of conditions, and this she has done in two very different ways—one bad, one good. The bad way has been by making him near-sighted. The near-sighted eye is at rest when looking at near objects. It is, however, always a diseased eye. Moreover, it sees poorly at a distance (often at near also) except when fitted with lenses. And it not infrequently goes blind from internal hemorrhage and detachment of the sensitive plate, or retina. The good way in which Nature is trying to help man in his modern conditions of existence is simply by strengthening his focusing apparatus for near points: chiefly, that is, by improving the elasticity of the lens. It is, I am firmly convinced, the normal-sighted eye, supplied with a very strongly developed focusing apparatus for near objects, which will survive the competition between the two kinds of eyes.

THE HUMAN EYE HEREAFTER—SPECULATION

Later, the falciform process, or something similar to it, may be re-developed. Man will then have "negative" accommodation. I also feel that, in the course of generations, man's "field" of view will become smaller and smaller. This, because his need of a wide field is growing less and less.

This I say with full realization that we live in an age of automobiles, and that these vehicles render desirable a wide field of view. The automobile is probably a very transitory phenomenon. I even believe that, in the course of countless ages, the two human eyes will come closer and closer together, the bridge of the nose will further diminish and sink (just as the animal snout, in man's line of descent, has been doing for vast æons of time) and, finally, man's two eyes will again become one—just one large, central, cyclopean eye. It is likely that the merely servient (left) eye will shrink away (as the pineal eye has already done) so that the right eye will become the cyclopean. Certain it is that the left eye, even today, is being used less and less continually. Man's binocular and stereoscopic visions are being destroyed. That is the price he pays for his speech center. The great cyclopean eye, however, will regain stereoscopic vision by developing two maculae in the one eye, just in the fashion in which many birds have stereoscopic vision in each eye now. Although the field of view will then be narrower than now, the eye will probably be microscopic and telescopic; it will be exceedingly acute for colors, for motion, and for form; and, finally, most important of all, it will probably be able to perceive as light many forms of energy which now produce in human eyes no sort or kind of perception.

At all events, the law of evolution is as interminable as the law of gravitation. I may be mistaken in my prophecy of the exact changes which are yet to occur in the human eye, but, on one point, surely, it is impossible to be mistaken. That point is that there will be change. The entire spiritual, intellectual and physical universes in which man lives will change. And man himself, his eyes included, will inevitably change with them.

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